EXPERIMENT - III

STUDIES ON RECTIFIER AND POWER SUPPLY

OCTOBER 06

Introduction to Electronics Lab (EC29003)

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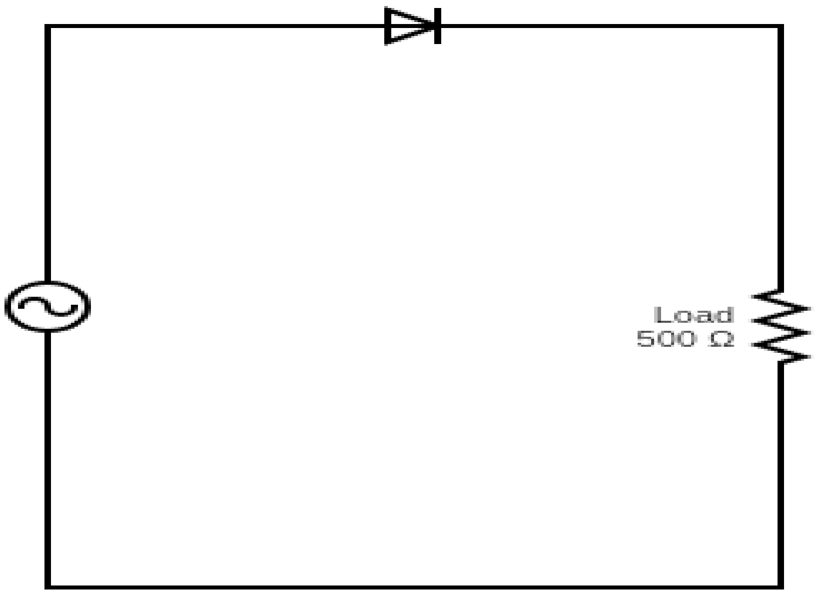
Objective : *Through this experiment, we get familiarized with wotking and different parameters of rectification using half wave rectifier, full wave rectifier(bridge rectifier) and full wave rectifier with filter.*

Part -I: Half-Wave Rectifier

- **Aim:** To see the working of a half wave rectifier and calculate the ripple factor and peak current.
- **Circuit Diagram:**



- **Theory:**

Diode is a passive electrical component that allows current to flow on in one direction(from anode or positive terminal to cathode or negative terminal). In the circuit above, as long as the input voltage is above the threshold voltage of the diode, the diode conducts and the output signal obtained follows the input voltage with a slight drop across the diode. However, when the voltage is below the threshold voltage in the negative half cycle, the diode is reverse biased and the entire voltage is dropped across diode and no output is obtained. Hence a pulsating DC output with some positive average value is obtained. This is called rectification.

When $V_s > V_\gamma$, the diode is forward biased and conducts.

$$I = \frac{V_s - V_\gamma}{R}$$

$$V_{out} = IR = V_s - V_\gamma$$

In the remaining time when $V_s < V_\gamma$, the diode is reversed biased and does not conduct.

$$V_{out} = 0$$

$$V_m = V_{out,peak} = V_{s,peak} - V_\gamma$$

Peak Inversion voltage

This signifies the maximum reverse bias voltage across the diode. The diode must be able to handle this voltage without going into breakdown region for proper rectification of the signal.

For a half wave rectifier this peak inversion voltage is

$$PIV = V_{s,peak}$$

Peak current

When the diode is in forward bias, the resistance of the external circuit is responsible for limiting the current across the diode. The peak current that flows through the diode is

$$I_{peak} = \frac{V_m}{R}$$

Average output voltage

The average voltage can be obtained by just averaging the function over a time period. For simplicity we can assume ideal diode in which V_γ is small and so the diode conducts for almost the entire half cycle.

$$V_{DC} = \frac{1}{T}\int_0^T V_{out} dt = \frac{1}{T}\int_0^{T/2} V_{out}\, dt \approx \frac{V_m}{\pi}$$

RMS output voltage

The RMS output voltage can be obtained by

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T {V_{out}}^2\, dt} = \sqrt{\frac{1}{T}\int_0^{T/2} {V_{out}}^2 dt} \approx \frac{V_m}{2}$$

AC output voltage

The AC and DC components are considered to be orthogonal to each other and add up to the RMS voltage.

$$V_{AC}^2 + V_{DC}^2 = V_{rms}^2$$

$$V_{AC} = \sqrt{V_{rms}^2 - V_{DC}^2} \approx 0.385V_m$$

Ripple Factor

The ripple factor is defined as the ratio of AC and DC voltage of the signal. It is a measure of how well the output has been rectified with a smaller ripple factor signifying better rectification. For a half wave rectifier,

$$ripple\ factor = \frac{V_{AC}}{V_{DC}} = \sqrt{\frac{V_{rms}^2}{V_{DC}^2} - 1} \approx 1.21$$

Procedure:

The experiment data is taken from falstad simulation, The procedure is as follows:

1. The half wave rectifier circuit is opened.
2. The frequency and amplitude of ac source is set to 5V, 50Hz. The load resistance is set to 300Ω.
3. The circuit is simulated.
4. The output voltage graph is noted. Reading of Vm and Vrms are taken.
5. Now, the amplitude and frequency of ac source and the load resistance is varied. Step 2,3,4 are repeated to take a set of readings.

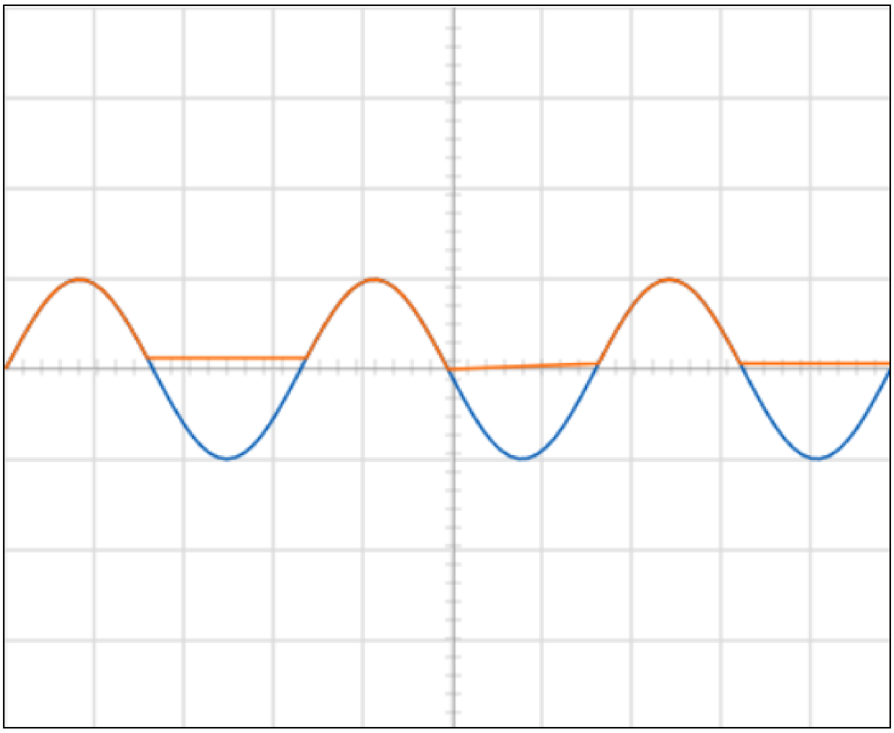
Observation:

Vin	frequency(Hz)	R(ohm)	I peak	Vm	Vrms	Vdc	Vac	ripple factor
1	50	100	4.7	0.47	0.235	0.149606	0.181227	1.21136
1.5	50	100	9.4	0.94	0.47	0.299211	0.362454	1.21136
2	100	200	7.25	1.45	0.725	0.461549	0.559104	1.21136
3	150	400	6.145	2.458	1.229	0.782406	0.947778	1.21136
4	50	300	11.41667	3.425	1.7125	1.090211	1.320642	1.21136
5	100	200	21.96	4.392	2.196	1.398017	1.693507	1.21136
8	150	400	18.5	7.4	3.7	2.355493	2.853358	1.21136
10	50	500	18.8	9.4	4.7	2.992113	3.624536	1.21136
		Considering Vrms Reading from falstad						
1	50	100	4.7	0.47	0.2	0.149606	0.132733	0.887222
2	100	200	7.245	1.449	0.7	0.461231	0.52656	1.141642
3	150	400	6.145	2.458	1.16	0.782406	0.856412	1.094588
4	50	100	33.69	3.369	1.615	1.072386	1.207565	1.126054
5	100	200	21.96	4.392	2.119	1.398017	1.592391	1.139036
8	150	400	18.5	7.4	3.595	2.355493	2.71582	1.152973
10	50	500	18.8	9.4	4.625	2.992113	3.526739	1.178678

Plot:

The red curve shows output voltage characteristics.

The blue curve is the input voltage.

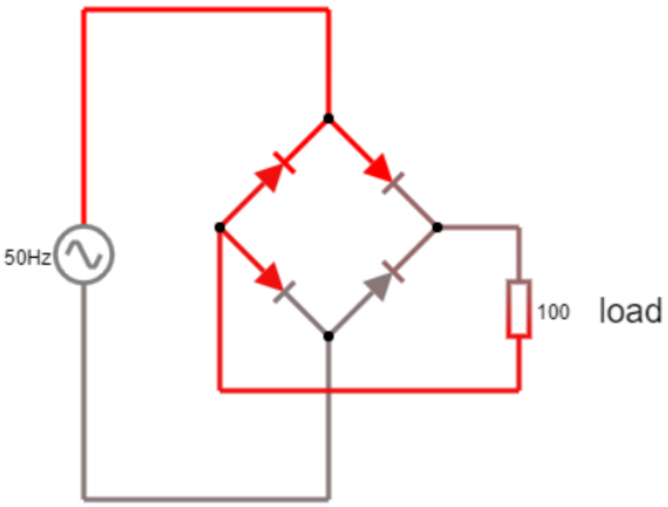


Discussion:

1. The oscilloscope is connected between the terminals of diode in vlabs, whereas it should be connected across the resistance.
2. The plot shows the voltage across the resistance, but has some problems. The peak current indicates that the diode has some cutoff voltage but the plot shows that it is operational for the entire positive half cycle. In reality it will be switched off during some portion of the positive half cycle when the input is positive but less than cutoff voltage and also the peak to peak voltage will be slightly lower.
3. While taking reading, only Vm is taken from falstad simulation and rest of the parameters are calculated using formula due to technical limitations. So, the ripple factor also came out to be ideal. The calculation using Vrms from simulation is also shown.
4. The input voltage is fed to the rectifier circuit through a step down auto-transformer to keep the voltage across diode below its breakdown voltage.
5. Slightly inclined baseline observed in the plot is due to the capacitance present in the oscilloscope to pass ac components in series with the circuit.

Part -II: Full-Wave Rectifier

- **Aim:** To see the working of a full wave bridge rectifier and calculate the ripple factor and peak current.
- **Circuit Diagram:**



- **Theory:**

In the circuit shown,

When $V_s > 2V_\gamma$, the diode is forward biased and conducts.

$$I = \frac{V_s - 2V_\gamma}{R}$$

$$V_{out} = IR = V_s - 2V_\gamma$$

In the remaining time when $V_s < 2V_\gamma$, the diode is reversed biased and does not conduct.

$$V_{out} = 0$$

$$V_m = V_{out,peak} = V_s - 2V_\gamma$$

Peak Inversion voltage

This signifies the maximum reverse bias voltage across the diode. The diode must be able to handle this voltage without going into breakdown region for proper rectification of the signal.

For a half wave rectifier this peak inversion voltage is

$$PIV = V_{s,peak} - V_\gamma$$

Peak current

When the diode is in forward bias, the resistance of the external circuit is responsible for limiting the current across the diode. The peak current that flows through the diode is

$$I_{peak} = \frac{V_m}{R} = \frac{V_{s,peak} - 2V_\gamma}{R}$$

Average output voltage

The average voltage can be obtained by just averaging the function over a time period. For simplicity we can assume ideal diode in which V_γ is small and so the diode conducts for almost the entire cycle.

$$V_{DC} = \frac{1}{T}\int_0^T V_{out} dt = \frac{1}{T}\int_0^T V_m\, dt = \frac{2V_m}{\pi}$$

RMS output voltage

The RMS output voltage can be obtained by

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T {V_{out}}^2\, dt} = \sqrt{\frac{1}{T}\int_0^{T/2} {V_m}^2 dt} = \frac{V_m}{\sqrt{2}}$$

AC output voltage

The AC and DC components are considered to be orthogonal to each other and add up to the RMS voltage.

$$V_{AC}^2 + V_{DC}^2 = V_{rms}^2$$

$$V_{AC} = \sqrt{V_{rms}^2 - V_{DC}^2} \approx 0.307V_m$$

Ripple Factor

The ripple factor is defined as the ratio of AC and DC voltage of the signal. It is a measure of how well the output has been rectified with a smaller ripple factor signifying better rectification. For a half wave rectifier,

$$ripple\ factor = \frac{V_{AC}}{V_{DC}} = \sqrt{\frac{V_{rms}^2}{V_{DC}^2} - 1} \approx 0.483$$

Procedure:

The experiment data is taken from falstad simulation, The procedure is as follows:

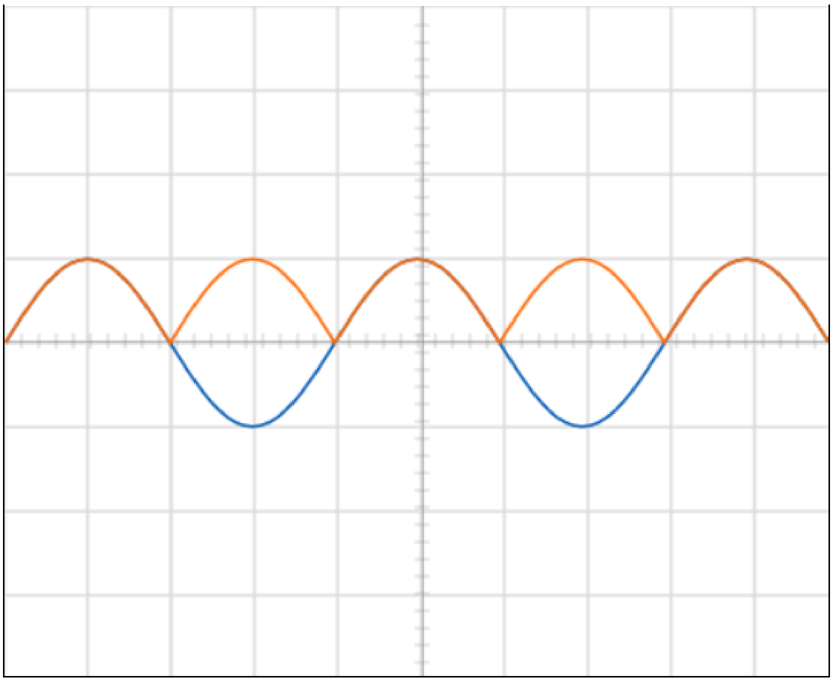
6. The full wave rectifier circuit is opened.
7. The frequency and amplitude of ac source is set to 5V, 50Hz. The load resistance is set to 300Ω.
8. The circuit is simulated.
9. The output voltage graph is noted. Reading of Vm and Vrms are taken.
10. Now, the amplitude and frequency of ac source and the load resistance is varied. Step 2,3,4 are repeated to take a set of readings.

Observation:

Vin	frequency(Hz)	R	I peak (mA)	Vm	Vrms	Vdc	Vac	ripple factor
1	50	100	1.01	0.101	0.071418	0.064299	0.031084	0.48343
1.5	50	100	4.48	0.448	0.316784	0.285206	0.137876	0.48343
2	50	200	4.71	0.942	0.666095	0.599696	0.289908	0.48343
3	50	100	18.04	1.804	1.275621	1.148462	0.555196	0.48343
4	50	400	7.245	2.898	2.049195	1.844924	0.891884	0.48343
5	50	300	12.42666667	3.728	2.636094	2.373319	1.147324	0.48343
10	50	500	17.612	8.806	6.226782	5.606074	2.710121	0.48343
		Considering Vrms Reading from falstad						
4	50	100	27.6	2.76	1.789	1.757071	0.336488	0.19150
5	100	200	18.99	3.798	2.505	2.417882	0.654883	0.27085
8	150	400	17.025	6.81	4.584	4.335381	1.489138	0.34348
10	50	500	17.612	8.806	6.04	5.606074	2.248007	0.40099

Plot:

The red curve shows output voltage characteristics.
The blue curve is the input voltage.

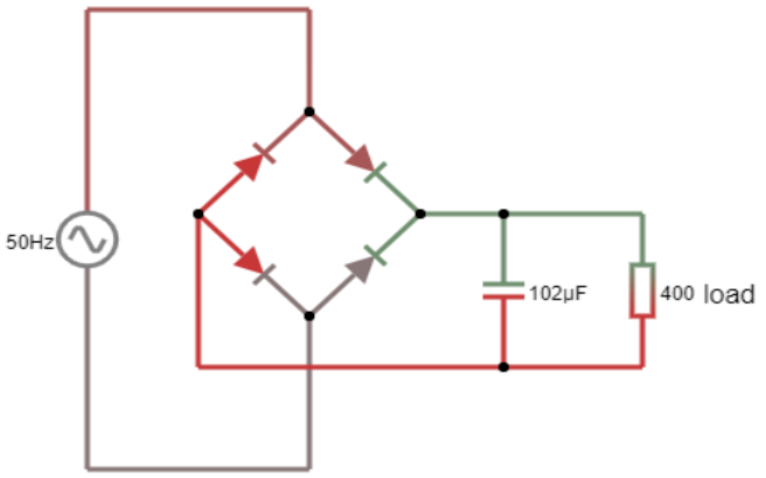


Discussion:

1. Full wave rectifier has less AC component in output than half wave rectifier. The DC component is also larger since output is obtained for almost the entire period rather than just half the period.
2. Bridge rectifier is better than centre tap in some aspects. Although it requires 4 diodes, the PIV of the diodes are less. Smaller transformer would be sufficient since entire output of transformer is used in rectification. In centre tap only half of the output is utilised.
3. The output obtained is quite ambiguous since there seems to be no drop of voltage in plot whereas the current obtained indicated threshold voltage of a single diode was taken into consideration while a bridge rectifier should ideally drop voltage across two diodes.
4. While taking reading,
Only Vm is taken from falstad simulation and rest of the parameters are calculated using formula due to technical limitations. So, the ripple factor also came out to be ideal. The calculation using Vrms from simulation is also shown.
5.The Vdc in case of full wave rectifier is almost double of that of the half wave. This is due to the fact that, in the full wave both the cycles exist in the output.

Part -III: Full-Wave Rectifier with Filter:

- **Aim:** To see Capacititive Rectification on a full wave bridge rectifier.
- **Circuit Diagram:**



- **Theory:**

As long as the voltage of the rectified signal increases the capacitor just stores this charge. But when the rectified voltage has reached its peak and starts reducing, the capacitor reverses biases the diodes and cuts off the entire supply circuit and stores the voltage across it in ideal case. If load is connected a part of it would be slowly discharged through resistor. If it loses some voltage then the supply circuit will only become active when the rectified unfiltered output is more than voltage across capacitor and remain active till peak is reached after which the supply again disconnects and the cycle repeats.

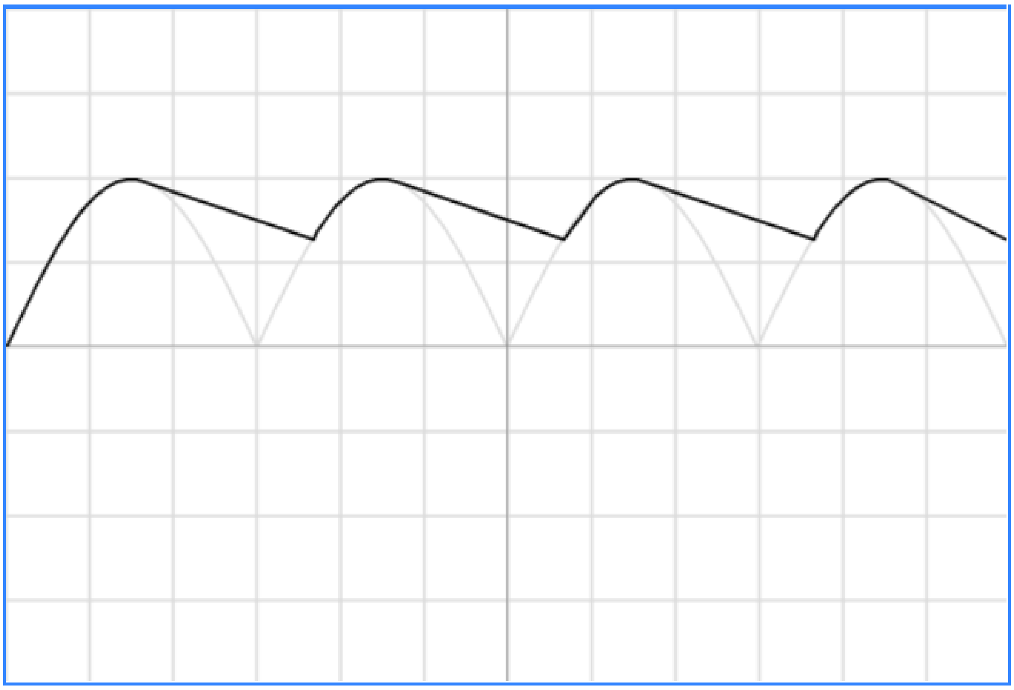
Thus, in essence much of the AC component is filtered out from the output and a large DC component remains.

In ideal case the ripple voltage V_r tends to zero, i.e. the time constant of the capacitor τ = infinte.

For practical case, The ripple voltage is considered to be,

$$V_r = \frac{V_m}{2fRC}$$

Plot:



Discussion:

1. The ideality of the diodes stands out since it is seen that the peak voltage remains the same as peak input voltage.
2. The capacitor values are not exactly supplied so the ripple factor cannot be calculated theoretically. However. from the graphs a estimate can be made.
3. For same capacitor and load resistor, it is seen that the full wave rectifier has lower ripple factor than half wave rectifier which means the ripples in full wave rectifier is less. This is because the capacitor discharges for longer in half wave rectifier throughout the entire half cycle. In full wave rectifier capacitor discharges for approximately half of the time as compared to half wave rectifier.